(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 598 950 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **92203647.0**

(51) Int. Cl.[5]: **G02B 26/10, G02B 5/08**

(22) Date of filing: **26.11.92**

(43) Date of publication of application:
01.06.94 Bulletin 94/22

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IT LI LU MC NL PT SE

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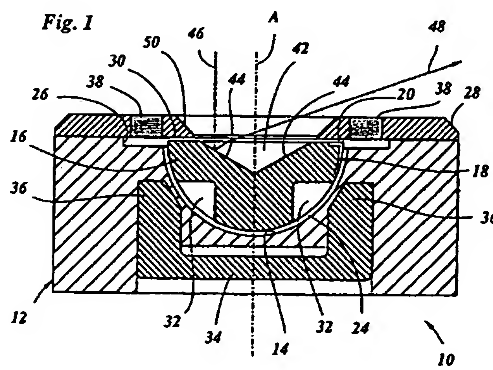
(54) **Rotary mirror system.**

(57) Rotary mirror system for angularly deflecting a light beam (46,48), said system comprising an air bearing (18,20,24,30) rotatably supporting a mirror body (16) on which one or more mirror facets (44) are provided, said mirror body being the rotor of an electric motor (32,34,36), wherein said mirror facets (44) are the side surfaces of an internal pyramid or frusto-pyramid (42) formed in and opening towards one axial end surface (22) of the mirror body and having an axis of symmetry coinciding with the rotational axis (A) of the mirror body, the orientation of the mirror facets (44) relative to the incoming light beam (46) being such that the reflected beam (48) leaves the internal pyramid at an inclined angle with respect to the rotational axis (A).

Fig. 1



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This invention relates to a rotary mirror system for angularly deflecting a light beam, said system comprising an air bearing rotatably supporting a mirror body on which one or more mirror facets are provided, said mirror body being the rotor of an electric motor.

Such rotary mirror systems are used for example in laser printers for deflecting the laser beam in the main scanning direction.

A system of the type indicated above is described in JP-A-1-285 917. In this known system, the mirror body is shaped as a polygonal disc with mirror surfaces provided at the outer circumferential edge surfaces of the disc. The disc is provided with magnets which co-operate with magnets of a stator, thereby constituting an electric motor for driving the disc. The disc is rotatably supported on the stator by means of an air bearing which is formed by two hemispherical members provided at the center of the disc on the opposing main surfaces thereof and received in mating hemispherical cavities formed in bearing members of the stator. The hemispherical bearing surfaces are provided with spiral grooves for introducing air into the narrow gap between the mating bearing surfaces, so that an air cushion for providing a low-friction bearing is established.

In this known device, the magnets are provided within the disc outwardly of the hemispherical bearing members, and the mirror facets are again disposed outwardly of the magnets, so that the disc as a whole must have comparatively large radial dimensions and accordingly a large moment of inertia. This makes it difficult to control gyro-effects, when the laser printer is moved or shocks are applied thereto while the mirror is rotating. Further, the large radial dimensions of the disc result in correspondingly large centrifugal forces which, in view of the limited mechanical strength of the disc, impose an upper limit to the achievable rotary speed. On the other hand, a rotary speed as high as possible would be desirable in order to provide a high printing efficiency.

Another problem encountered with the above-described prior art relates to the so-called wobble, i.e. an undesired deflection of the reflected beam in the direction normal to the scanning direction. This wobble is caused by slight misalignments of the mirror facets due to manufacturing tolerances, and by the minor play in the air bearing which may lead to slight vibrations or oscillations of the rotating mirror body. Due to the comparatively large mass and moments of inertia of the mirror body, the frequency of these oscillations may be in the range of the rotational frequency of the mirror body, so that slight imbalances of the mirror body may lead to resonance problems.

In DE-A-29 27 199 a wobble-free rotary mirror system has been proposed in which, however, the light beam is not angularly deflected but is subject to an oscillating parallel displacement. In this device, an internal roof prism is excentrically provided in one axial end surface of the rotating mirror body, the mirror facets being formed by the angled internal surfaces of this roof prism. The incoming light beam is aligned with the axis of rotation, and is subject to double-reflexion at both mirror facets, such that the outgoing beam is again parallel with the incoming beam but radially outwardly offset relative thereto. Due to the rotation of the mirror body, the outgoing beam rotates about the incoming beam. One component of the two-dimensional rotating movement of the reflected beam is cancelled by a cylinder lens, so that an oscillating one-dimensional movement is achieved at the focus of the cylinder lens. This system is substantially wobble-free because the outgoing beam after double-reflexion is always parallel to the incoming beam, irrespective of slight angular displacements of the axis of the mirror body. However, with this device, the amplitude of the oscillating movement of the reflected beam is not larger than the diameter of the mirror body. Accordingly, this system is not suited for obtaining large scanning widths.

In US-A 4 662 709, a mirror system is proposed in which mirror facets are formed by the side surfaces of an internal frusto-pyramid formed in one axial end surface of the rotating mirror body. The incoming light beam is reflected at one of the mirror facets into the interior of the frusto-pyramid and undergoes two reflexions at fixed mirror surfaces provided stationarily within said internal pyramid, so that the light is reflected back to the mirror facet where it is reflected for a second time. In this system, the mirror body must also have large radial dimensions, because the stationary mirrors have to be accommodated in the interior of the internal pyramid formed in the mirror body.

US-A 4 475 787 discloses a single facet wobble-free light scanner which utilizes a pentaprism as rotating mirror body. The incoming light beam is aligned with the axis of rotation of the prism and enters through one surface of the prism which is normal to the axis of rotation. The light beam is then reflected at two inner surfaces of the prism and leaves the prism through another surface at right angles to the incoming beam. A problem involved in this structure is that the pentaprism is not symmetric with respect to the axis of rotation, so that it is difficult to balance the rotating mirror body accurately enough for permitting a high speed of revolution.

It is an object of the invention to provide a rotary mirror system which has a simple and compact construction and can be operated at high

speeds.

This object is achieved by a rotary mirror system according to the preamble in which said mirror facets are the side surfaces of an internal pyramid or frusto-pyramid formed in and opening towards one axial end surface of the mirror body and having an axis of symmetry coinciding with the rotational axis of the mirror body, the orientation of the mirror facets relative to the incoming light beam being such that the reflected beam leaves the internal pyramid at an inclined angle with respect to the rotational axis.

Since, according to the invention, the mirror facets are formed in an axial end face of the mirror body, the mirror body can be made small and light in weight, so that it has a low moment of inertia and can be operated at very high speeds of revolution without inducing excessive centrifugal forces. The internal pyramid contributes to the reduction in mass of the mirror body and, as it has an axis of symmetry coinciding with the rotational axis, the mirror body may easily be balanced so that it behaves like a symmetric top. In addition, the symmetric configuration of the internal pyramid is suitable for providing a multiple facet mirror. Since the mirror facets are formed by the inner surfaces of a pyramid-shaped cavity in the mirror body, it is not necessary to provide the mirror body with any projecting parts which would be subject to destructive mechanical stresses induced by the centrifugal forces at extremely high speeds. In the system according to the invention, the air bearing may be provided on the complete circumferential surface of the mirror body, so that the whole mirror body is well supported against minor imbalances and a stable and hence wobble-free rotation of the mirror body can be achieved. Nevertheless, since the reflected light beam leaves the internal pyramid at an inclined angle with respect to the rotational axis, the rotation of the mirror body induces an angular displacement of the reflected beam about the rotational axis, so that the exposure spot at the downstream end of the reflected beam can be moved over a large scanning width.

Optional features and useful further developments of the system according to the invention are indicated in the dependent claims.

Preferably, a pyramid-shaped transparent body is fitted into the internal pyramid of the mirror body, and the mirror facets are formed by a mirror finish such as a metal plating or the like on the side surfaces of the transparent pyramid-shaped body. If a sectional plane including the axis of rotation is considered, the optical properties of the transparent body are those of a prism. This is why the transparent body shall be termed "prism" hereinafter, although, geometrically, it is a pyramid rather than a prism.

The surfaces of the prism forming the mirror facets can be machined with very high accuracy. Thus, a multiple-facet mirror with exactly adjusted mirror facets can be manufactured by forming a cavity with a roughly pyramidal shape in the end face of the mirror body and then inserting the precisely machined prism with the mirror finished side faces thereinto. The prism may be fixed within the cavity by means of an adhesive and is securely supported against centrifugal forces by the surrounding walls of the cavity.

In addition, the refractive properties of the prism may be utilized for reducing or completely cancelling the wobble effect.

The mirror body may have a cylindrical shape with the air bearing being provided on the whole cylindrical surface.

In a preferred embodiment, however, the mirror body is shaped as a hemisphere with air bearings provided on the whole hemispherical surface and on the circumferential edge portion of the flat surface, the internal pyramid being provided in the central part of the flat surface. This embodiment has a very simple, compact and light-weight construction.

The mirror body may then be manufactured by bisecting a metal ball which is normally used in all bearings. Such balls with perfectly machined spherical surfaces, i.e. with surface tolerances of 0.1 μ or less are commercially available at low costs. Thus, the invention makes it possible to provide a low-cost rotary mirror system for a compact laser printer which nevertheless offers a high resolution and/or printing speed.

Preferred embodiments of the invention will be explained below in conjunction with the accompanying drawings, in which:

Fig. 1 is a sectional view of a rotary mirror system according to the invention,

Fig. 2 is a lateral view of a mirror body used in the system according to Fig. 1, and

Fig. 3 is a plan view of the mirror body.

As is shown in Fig. 1, a rotary mirror system 10 comprises a stator block 12 defining a hemispherical bearing shell 14, and a hemispherical mirror body 16 which is rotatably supported in said bearing shell. The mirror body 16 has a diameter of about 10 mm.

As can best be seen in Figs. 2 and 3, the mirror body 16 is formed with helical grooves 18 which extend from the circumferential edge over the upper part of the spherical surface, and with spiral grooves 20 which extend from the circumferential edge of the mirror body over the outer circumferential portion of the plane top surface 22 thereof. In Fig. 1, the depth of the grooves 18 and 20 is exaggerated. In practice, the depth of these grooves is only in the order of a few μ. When the

mirror body 16 rotates in counter-clockwise direction in Fig. 3, the inclined grooves 18 serve to ventilate air into a narrow gap 24 between the mating spherical surfaces of the bearing shell 14 and the mirror body 16, thereby forming a dynamic air bearing.

The top surface of the stator block 12 is formed with a shallow recess 26 which surrounds the bearing shell 14. A ring 28 which is secured to the top surface of the stator block 12 covers the outer circumferential portion of the recess 26 as well as the outer circumference of the mirror body 16. A narrow gap 30 is defined between the top surface 22 of the mirror body 16 and the bottom surface of the inner portion of the ring 28. The grooves 20 serve to introduce air into the gap 30. Since the grooves 20 do however not extend to the inner circumference of the ring 28 which is shown by a phantom line in Fig. 3, an air cushion with an increased air pressure is formed in the gap 30, thereby constituting another air bearing which holds the mirror body 16 in the bearing shell 14 and provides exact alignment of the axis of rotation normal to the plane of the ring 28.

In the shown embodiment, the lower portion of the hemispherical mirror body 16 is formed with a cutout which accommodates a permanent magnet 32. The stator block 12 accommodates a yoke 34 which has magnetic poles 36 opposing the magnet 32. The yoke 34 is provided with electric coils (not shown) and constitutes the stator of an electric motor for driving the mirror body 16. The rotor of this electric motor is formed by the mirror body 16 itself, which is provided with the permanent magnet 32. Alternatively, the metal body of the mirror body 16 may be magnetized as a whole.

The ring 28 is provided with bores with filters 38 inserted therein for supplying clean air to the air bearings.

A recess 40 in the shape of an inverted pyramid is formed in the center portion of the plane top surface 22 of the mirror body 16. The base of the pyramid 40 which lies in the plane of the surface 22 is generally shaped as a regular polygon (as a square in the shown embodiment). The center of the base polygon as well as the tip of the pyramid lie on the rotational axis of the mirror body 16. Thus, the pyramid 40 has an axis of symmetry (symmetry under rotations about 90° in the shown embodiment) which coincides with the axis of rotation of the mirror body 16.

An optical prism 42 which has the same pyramid shape as the recess 40 is fitted in the recess 40 and secured therein by means of an adhesive, for example. The triangular side surfaces of the recess 40 or, more precisely, the corresponding side surfaces of the prism 42 form mirror facets 44 for deflecting a light beam 46 in the manner shown in Fig. 1. Before the prism 42 has been inserted into the recess 40, the side surfaces of the prism have been accurately machined and mirror finished and plated with a reflective coating (a metal coating for example) and a protective surface layer.

As shown in Fig. 1, a light beam 46, for example, the modulated laser beam of a laser printer, is incident on the mirror body 16 in a direction parallel with the axis of rotation A, but is laterally offset therefrom. Thus, the incoming light beam 46 passes the base surface of the prism 42 at right angles, i.e. without refraction, is reflected at the mirror facet 44 and then undergoes refraction at the base surface of the prism 42. Thus, the reflected beam 48 forms an angle of slightly less than 90° with the axis of rotation A of the mirror body. The inner periphery of the ring 28 is formed with a conical surface 50 so as to avoid interference with the reflected beam 48.

When the mirror body 16 is rotated about the axis A, the reflexion plane which is the plane of the drawing in Fig. 1 is also rotated, and thus an angular displacement of the reflected beam 48 is achieved.

This reflected beam describes a slight curvature. In case that the mirror system is used for exposure of a photoconductive layer disposed on a drum, it is preferred to correct this curved path by means of a correcting prism positioned between drum and mirror facet 44. Also a mirror or lense can be used for this purpose.

With the above-described construction, the mirror body 16 is extremely compact and light-weight, so that very high rotational speeds can be achieved without inducing excessive centrifugal forces. The air bearings support the mirror body with a minimum of friction and at the same time with minimal play. Since the mass of the mirror body 16 is comparatively low and a high air pressure is generated in the gaps 24 and 30, the natural frequency of oscillations of the mirror body within the air bearing is much higher than the rotational frequency, so that resonance problems are avoided and a stable rotation of the mirror body is achieved. Since the mirror facets 44 of the prism 42 can be machined precisely, all the factors which could result in a wobble of the reflected laser beam 48 are largely eliminated.

The structure described above further has the advantage that the mirror facets 44 are protected against dust and humidity. Since the air for the air bearing is sucked-in through the filters 38 and is forced through the gap 30 and then blown out through the central opening of the ring 28, the top surface of the prism 42 is also protected against dust.

If the axis of the mirror body 16 is tilted by a small angle, the direction of the outgoing laser

beam 48 is deviated by twice this angle, due to reflexion at the mirror facet 44.

However, since the refractive top surface of the prism 42 is also tilted, the refraction of the beams 46,48 at this surface is changed such that the deviation of the outgoing beam 48 is at least partly compensated.

To optimize this compensation, a prism shaped as a double-pyramid can be used instead of the prism 42 shown in Fig. 1.

Claims

1. Rotary mirror system for angularly deflecting a light beam (46,48), said system comprising an air bearing (18,20,24,30) rotatably supporting a mirror body (16) on which one or more mirror facets (44) are provided, said mirror body being the rotor of an electric motor (32,34,36), characterized in that said mirror facets (44) are the side surfaces of an internal pyramid or frusto-pyramid (40,42) formed in and opening towards one axial end surface (22) of the mirror body and having an axis of symmetry coinciding with the rotational axis (A) of the mirror body, the orientation of the mirror facets (44) relative to the incoming light beam (46) being such that the reflected beam (48) leaves the internal pyramid at an inclined angle with respect to the rotational axis (A).

2. Mirror system as claimed in claim 1, wherein a pyramid-shaped optical prism (42) is fitted in the internal pyramid (40) formed in the mirror body (16).

3. Mirror system as claimed in claim 2, wherein the side surfaces of the prism (42) are provided with a reflective coating to form said mirror facets (44).

4. Mirror system as claimed in claim 3, wherein said prism (42) is bonded to the mirror body (16) by means of an adhesive applied on the side surfaces of the internal pyramid.

5. Mirror system as claimed in anyone of the preceding claims, wherein said mirror body (16) has a hemispherical shape and is received in a hemispherical bearing shell (14) formed in a stator block (12), said air bearing being provided between the mating hemispherical surfaces of the mirror body and the bearing shell.

6. Mirror system as claimed in claim 5, wherein said stator block (12) is covered by a ring (28) the inner circumferential edge portion of which projects over the flat surface (22) of the mirror body (16), another air bearing (18,30) being formed between the flat surface (22) of the mirror body (16) and the surface of the ring (28) opposed thereto.

7. Mirror system according to claim 6, wherein said ring (28) is provided with air filters (38) for introducing air to be supplied to the air bearings into a recess (26) which surrounds said bearing shell (14).

Fig. 1

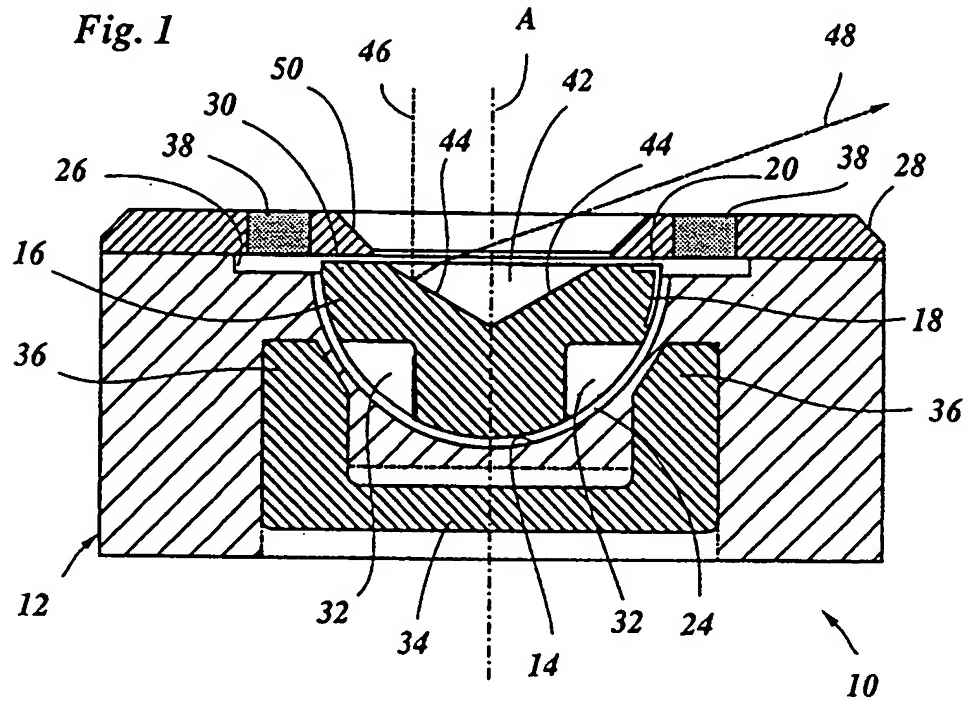


Fig. 2

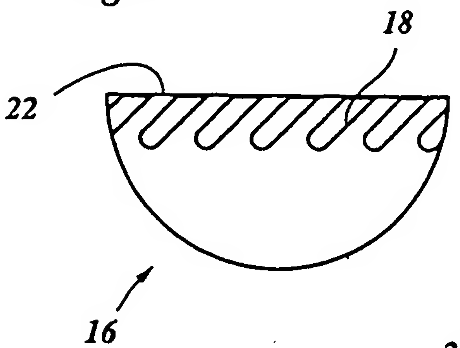
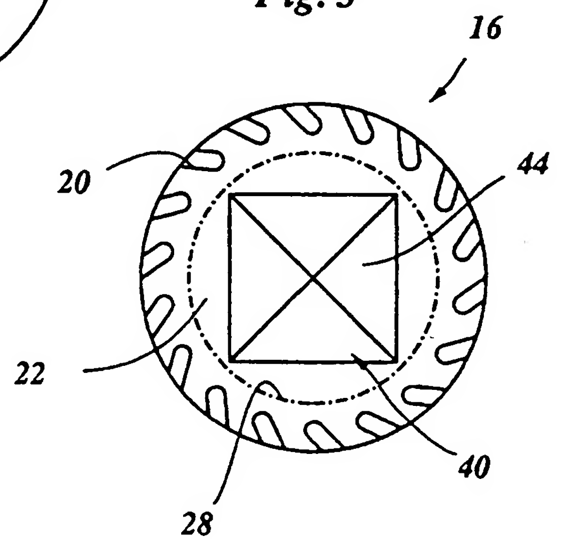


Fig. 3



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EUROPEAN SEARCH REPORT

Application Number

EP 92 20 3647

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y,D	PATENT ABSTRACTS OF JAPAN vol. 014, no. 061 5 February 1990 & JP-A-01 285 917 (RICOH) 16 November 1989 * abstract *	1,2,4,5	G02B26/10 G02B5/08
Y	JP-A-04 226 415 (RICOH) * claims; figures *	1,2,4,5	
Y	DE-A-4 001 242 (TELEFUNKEN) * claims; figures *	1,5	
Y	EP-A-0 444 958 (FUJITSU) * claims; figure 13 *	1,5	
A	US-A-4 772 136 (CARTER) * claims; figures *	1,5,6,7	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G02B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 JULY 1993	PFAHLER R.

CATEGORY OF CITED DOCUMENTS

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